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Validation of a novel irritant gas syndrome triage algorithm

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Abstract

Objective: Our objective was to validate a novel irritant gas syndrome agent (IGSA) triage algorithm for use in an emergency department (ED). We assessed efficiency, accuracy, and precision of our IGSA triage algorithm based on signs/symptoms of actual patients.

Design: After characterizing the signs/symptoms of an actual IGSA exposure event, we developed and validated the IGSA triage algorithm using a simulated computer exercise to compare the IGSA triage algorithm to the preferred hospital triage algorithm, the Emergency Severity Index (ESI).

Setting: This study was a simulated computer exercise using surveys developed in Research Electronic Data Capture software. Nurse volunteers simulated triaging 298 patients.

Participants: Patient data included 146 patients treated during the disaster as well as 152 unexposed patients. Twenty-six nurse volunteers were assigned to triage the patients using one of the algorithms in the simulated computer exercise.

Main Outcome Measure(s): The precision of the IGSA triage algorithm was 0.82 (confidence interval [CI] 0.78-0.85) and ESI 0.73 (CI 0.69-0.77). Weighted κ for ESI and IGSA accuracy for exposed patients was 0.32 (95% CI 0.26-0.37) and 0.81 (95% CI 0.77-0.85), respectively.

Results: The IGSA triage algorithm was more accurate and precise than the ESI algorithm for triaging patients exposed to an irritant gas.

Conclusions: This study validates the IGSA triage algorithm as the basis for the development of a prototype software application to quickly identify victims of a chemical disaster and triage patients efficiently and accurately with the potential to dramatically improve the processing of patients in EDs.

Keywords

triage; chemical triage algorithm; methods for disaster research

Introduction

Chemicals are ubiquitous in the environment and, as such, we are exposed every day to a variety that could cause harm.¹ Producers and users of chemicals are scattered across the country, requiring a vast panoply of chemicals to be transported by rail, water, air, highway, or pipeline. Chlorine gas and anhydrous ammonia are the most common irritant gas syndrome agents (IGSA); others include sulfur dioxide, hydrogen fluoride, and a variety of additional chemicals that are important in manufacturing raw materials.² Transportation accidents, terrorism incidents, and industrial accidents involving IGSA pose threats to life and require rapid medical assessment by first responders and/or hospital personnel to reduce death and disability.³

During a chemical disaster, local hospital emergency departments (EDs) receive a surge of victims before any chemical exposure information is available. Most EDs operate day-to-day at or above capacity.⁴ The surge of patients during a disaster places additional stress on an already overburdened system, potentially placing patients at risk and challenging staff to efficiently process patients for appropriate care and treatment. Patient flow and processing have benefited little from the incorporation of technology despite the fact that they have much to gain.⁵ Studies by the Agency for Healthcare Research and Quality indicate that improving triage is one strategy for enhancing overall ED flow and that flexible and robust technology systems are needed to improve the treatment of patients in the ED.⁴

The early identification of mass casualty incidents (MCIs) involving IGSA is essential to an appropriate and rapid response for decontamination, triage, and treatment that could save thousands of lives. Our previous study of the Graniteville, SC (2005) chlorine disaster found the surge of victims into a local ED following a chlorine release resulted in: (1) confusion regarding the best triage methods; (2) difficulty with the efficient processing of patients; and (3) potentially undertriaged victims who experienced latent symptoms after discharge.^{6,7} Currently, there is no triage system that is appropriate to manage an IGSA MCI such as the Graniteville, SC, chlorine release in 2005 or the Minot, ND, anhydrous ammonia release in 2002.^{3,8-10} Therefore, the development of triage informatics tools to manage IGSA MCIs is essential.

Objectives

The main objective of this research is to develop and validate a novel IGSA triage algorithm to quickly identify chemical exposures based on presenting signs/symptoms (S/Sx) during a patient surge to an ED and efficiently and accurately triage patients. The validated IGSA

triage algorithm is intended to provide the logic model for the development of a prototype software application. Such technology will allow for the analysis of data to be collected across ED patients to quickly identify victims of a chemical MCI. The purpose of this publication is to briefly describe the development of the novel IGSA triage algorithm and more thoroughly describe the use of a computer simulation to test and validate the algorithm.

Research Design and Methods

Only de-identified data were used for this study. The Office of Research Compliance at the University of South Carolina determined this study exempt from the protection of human subjects' regulations. The research design included five steps: (1) abstracting S/Sx from medical records of victims from the Graniteville disaster; (2) analyzing the abstracted data to characterize the S/Sx of an IGSA exposure; (3) developing a novel IGSA triage algorithm; (4) testing the precision, accuracy, and efficiency of the algorithm compared to a typical hospital triage system (ie, the Emergency Severity Index [ESI]) using a computer-simulated exercise to recreate the surge following a chemical MCI; and (5) surveying nurse participants in the computer-simulated exercise following the exercise.

Step 1: Abstracting S/Sx from medical records of victims from the Graniteville disaster

Data were abstracted from 298 medical records including 146 patients exposed during the initial patient surge of the 2005 Graniteville chlorine exposure and 152 patients not exposed to chlorine (ie, 52 unexposed patients who presented in the ED during the 2005 incident and another 100 patients seen in the same ED in January 2015) that served as a comparison group. Only de-identified data were made available to the research team.

Step 2: Analyzing the data to characterize an IGSA exposure (ie, identify chlorine exposure S/Sx)

The Wireless Information System for Emergency Responders (WISER)¹¹ and the Chemical Hazards Emergency Medical Management Intelligent Syndromes Tool (CHEMM-IST),¹² developed by the National Library of Medicine, are decision support tools designed to assist emergency responders and first receivers with hazardous material incidents. Fourteen S/Sx used by CHEMM-IST and 79 S/Sx from WISER were used to map the data abstracted from the medical records to identify patterns and parameters that characterize an IGSA syndrome. The analysis showed that three clusters of S/Sx are statistically associated with an IGSA syndrome ($p < 0.01$). Figure 1 details the IGSA syndrome. The S/Sx associated with the syndrome was organized into three groupings: (1) respiratory, (2) chest discomfort, and (3) pain/irritation/burning of the eyes, nose, and throat.

Step 3: Developing a novel IGSA triage algorithm

The IGSA algorithm incorporated the three groupings of S/Sx associated with the IGSA syndrome. Additionally, findings from the previous study indicated that pulse oximetry (SpO_2) was very predictive of actual injury severity in a chemical MCI⁶ and therefore, a $\text{SpO}_2 < 92$ percent was determined to be a key consideration for triaging a patient as "Urgent." The determination of an actual or potential chemical exposure (needed

information for the “Known Chemical Incident Location” decision point in the IGSA triage algorithm) was a challenge because the actual address of the patient was not available to the researchers; however, an exposure or potential exposure could be gleaned from the abstracted medical record information. Figure 2 shows the IGSA triage algorithm used for the April 2016 computer simulation exercise.

Step 4: Developing a Gold Standard to serve as a basis for comparison

The research team first outlined the data elements and analysis steps required for an objective validation study. Next, three expert nurse clinicians on the research team used data abstracted from the medical records and they independently reviewed each of the 298 patients to determine the appropriate triage category using the IGSA triage algorithm and then the ESI algorithm. A consensus was reached where there was disagreement. This triage determination served as the Gold Standard for statistical comparison of the triage category of an individual patient as determined by the nurse during the simulated computer exercise to that agreed upon by the research expert clinicians.

Step 5: Designing a computer simulation exercise to test the accuracy, precision, and efficiency of the new algorithm compared to a commonly used hospital ED triage system (ie, the ESI)

The computer simulation triage objective was to test and validate the IGSA triage algorithm and compare its accuracy, precision, and efficiency with that of the standard ESI algorithm (see Figure 3).¹³

The research team determined the demographic and clinical data for each of the 298 patients to include on laminated cards formatted with the following information: (1) a simulated patient identifier; (2) patient age; (3) patient gender; (4) chlorine exposure; (5) patient’s vital signs including pulse oximetry, pulse rate, respiration rate, and pain scale (when available); and (6) the chief complaint. These patient information cards (IDs) provided the information for the nurses to use during the simulation exercise to triage the assigned patients. A sample card is provided in Figure 4.

Twenty-six nurses were recruited to participate in the drill through e-mail invitations, in-person invitations, and posters placed around the College of Nursing. The nurses’ ages ranged from 20 years to older than 60 years with 50 percent of the nurses in the 41- to 60-year range. Most nurses had a Master or terminal degree (80.7 percent). Ten nurses were employed in academic settings, 13 nurses were employed in clinical medical/surgical, pediatrics, critical care, gerontology, psych/mental health, oncology, or public health settings, one was an administrator, and two nurses were retired.

Each nurse was assigned to either the ESI or IGSA triage algorithm to ensure a balance between the two groupings with regards to education, years of experience, and practice setting. Twelve nurses were selected to use ESI and 14 for the IGSA triage algorithm during the computer simulation. The 298 patients were randomized into groups of 50 using a systematic sampling process. For analysis, each nurse was paired with another nurse and the pair was randomly assigned a group of 50 patients to assess twice for a total of 100 observations/paired nurse. The nurse and research team observations were blinded to this

nurse pairing and the assignment of patient groups. The nurses triaged patients using patient cards only, no actual or simulated patients were triaged. Completed patient cards were periodically collected by the research team members to ensure that the nurse could not review the triage category she had previously assigned a specific patient. Research team members also served as observers to assure this did not happen. This methodology allowed for analyses of inter-rater reliability and intra-rater reliability to determine the precision of each triage algorithm.

Prior to the start of the computer simulation, separate just-in-time trainings were provided to the nurses using IGSA and those using ESI. Fabricated patient cards were displayed so that the nurses could practice triaging using the assigned algorithm. Once the nurses seemed comfortable with the algorithm triage process and the patient cards, they were logged on to computers and given envelopes containing the patient cards for the actual patients they were to triage using the computer.

This methodological process allowed comparison between: (1) accuracy of nurse pairs using ESI and IGSA triage algorithms; (2) accuracy of ESI and IGSA triage algorithms with the Gold Standard; (3) precision of ESI and IGSA triage algorithms; (4) efficiency of ESI and IGSA triage algorithms; and (5) nurses' feedback on using ESI and IGSA triage algorithms. Simple and weighted κ statistics with 95% confidence interval (CI) were calculated to examine the level of agreement between each nurse pair. All data analyses were performed using SAS/STAT® version 9.4.^{14,15}

Development of the Computer Surveys Used for the Simulation

The research team utilized the survey capability in Research Electronic Data Capture¹⁶ (REDCap) software to develop two unique computer surveys: an IGSA survey and an ESI survey. The REDCap¹⁶ survey data entry forms were developed to mirror the questions and flow for each algorithm (Figures 2 and 3) with additional items (ie, nurse ID, patient ID, start time) to aid in the data analysis. The team developed the surveys so that they generated a recommended triage category based upon the responses to each section.

The initial section of the ESI survey contained the identifiers, the start time, age category, and the chief complaint (see Figure 5). The *Record ID* is a sequential number for each survey, the *Nurse ID* is a unique identifier assigned to each nurse. Nurses were instructed to press a "Now" button that appears to the right of the *Start time*. REDCap automatically stored an end time when a user completed a survey allowing calculation of the time spent on each survey. The remaining items on the survey were answered based upon the data from the patient cards. The age category selected influenced the values for respirations and heart rate that appeared in the VITAL SIGNS ASSESSMENT section. For example, if the age category was between 3 months and 3 years, the pediatric consideration vital sign values of concern would be respirations > 40/minutes, heart rate > 160/minutes. Regardless of age, a $\text{SpO}_2 < 92$ percent was to be triaged as "Urgent." The FINAL DECISION section of the survey form required the nurse to agree or disagree with the computer-generated triage level. If the nurse disagreed, a text box appeared that had to be completed by the nurse to explain why he or she disagreed with the assessment.

Similarly, the major sections of the IGSA computer survey (see Figure 6) mirror the IGSA triage algorithm along with a header section and a FINAL TRIAGE ASSESSMENT section. Because the IGSA triage algorithm has specific exit points, portions of the survey form were hidden from the nurse according to the answers provided and skip patterns were embedded. For example, if the nurse answered “Yes” to the “Patient meets criteria for LEVEL 1” question, an information message instructed the nurse to STOP the IGSA assessment process after completing THE LEVEL 1 ASSESSMENT section and advance to the FINAL TRIAGE ASSESSMENT at the bottom of the form.

Step 5: Surveying nurse participants after the exercise

The week following the computer simulation exercise, SurveyMonkey® was used to e-mail a triage exercise evaluation survey to all nurses who participated in the exercise. All data were collected anonymously. Twenty-five nurses completed the survey: 13 nurses were assigned to ESI and 12 nurses were assigned to IGSA. Nurses were asked five questions (see Table 1).

Results of the Validation Testing

Triage algorithms' accuracy as determined by agreement between nurse pairs

Simple and weighted κ statistics with 95% CI were calculated for the 13 nurse pairs (see Table 2). The ESI algorithm weighted results showed poor agreement for nurse pairs 1 and 9 and 5 and 12. Overall, the result revealed fair agreement for the other four pairs of nurses using the ESI algorithm. The weighted κ IGSA triage algorithm results indicated good to very good agreement for all pairs of nurses. The simple κ agreement for ESI and IGSA triage algorithm results ranged from 0.03 to 0.40 and from 0.54 to 0.83, respectively, with the weighted κ agreement for ESI algorithm and IGSA triage algorithm results ranged from 0.12 to 0.51 and ranged from 0.76 to 0.89, respectively. The IGSA triage algorithm κ agreement was significantly greater than the ESI algorithm (Table 2).

Triage algorithms' accuracy as determined by agreement with Gold Standard

Table 3 indicates the result of simple and weighted κ agreement for ESI and IGSA triage algorithm results with the Gold Standard. The patients were divided into two groups or samples based upon the year of the ED visit. The ESI algorithm results showed fair agreement with the Gold Standard for 2005 (simple κ 0.23 and weighted κ 0.36) and poor to fair agreement for 2015 (simple κ 0.18 and weighted κ 0.32). In contrast, the IGSA triage algorithm results indicated good to very good agreement with the Gold Standard for 2005 and 2015 (simple κ for 2005: 0.77 and for 2015: 0.72; and very good using weighted κ for 2005: 0.85 and for 2015: 0.81).

Triage algorithms' precision

Precision was measured by how well nurses triaged the same patient twice. This process is described above in Research Design and Methods section. The precision of the ESI algorithm was good while the precision was very good for the IGSA triage algorithm (see Table 4). The precision for ESI was 73 percent with 95% CI of 0.69-0.77, and the precision for IGSA was 82 percent with 95% CI of 0.78-0.85.

Triage algorithms' efficiency

The efficiency of each algorithm was measured as well. REDCap recorded when each nurse started and completed triaging each assigned patient. There was less than a 4 second difference in the triage time between nurses using the ESI algorithm and the IGSA algorithm (see Table 5).

Results of SurveyMonkey® post exercise survey

The results showed that the IGSA triage algorithm had higher means compared to ESI for all questions in SurveyMonkey (Table 6). The results of the parametric (*t* test) and nonparametric (Wilcoxon rank sum) tests indicated statistically significant results for quality of triage tool (mean for IGSA = 4.42 and ESI = 3.46 with *p* value = 0.0053).

Common themes related to Question 4 “What does the IGSA triage tool do really well?” included: (1) cuts time and streamlines the process for mass casualty triage allowing the nurse to quickly and accurately triage; (2) facilitates accurate performance of triage by people who have assessment skills but are not necessarily knowledgeable about the relevant symptoms; (3) gives a clear outline for triage—saving time and resources; and (4) provides a decision tree and a simple logical progression.

Common themes related to Question 5 “How can we improve the IGSA triage tool?” included: (1) the guidelines for the pediatric population (especially infant through preschool age) need to be more specific, and (2) the directions about the number of symptoms indicating IGSA syndrome are a little confusing as to which ones to count (eg, eyes/mouth burning count for one but different respiratory symptoms each count as one).

Discussion

The κ agreement (ie, between nurse pairs and the Gold Standard), precision results, and post exercise survey results show that the IGSA algorithm performed better than the ESI algorithm in triaging patients exposed to chlorine. These results validated the ability of the IGSA algorithm to potentially improve the triage process in the ED and patient outcomes. However, the findings from the computer exercise and feedback from the nurses using the IGSA algorithm indicated that some changes were needed to the algorithm for clarity and to enhance ease of use. Because the ED visits for all 298 patients occurred in January and many exhibited S/Sx of upper respiratory infections and/or influenza—the same S/Sx exhibited by those experiencing a chlorine exposure—the research team recognized the need to more accurately define the chlorine syndrome. Statistical analysis showed that at least one S/Sx from two of the three groupings was needed to be considered a syndrome. In addition, the verbiage “Grouping” was changed to “Cluster.”

During the computer simulation exercise, nurses using the IGSA triage algorithm were provided two decision points at the end of the process: (1) decide that the patient was Urgent or (2) monitor the patient for 6 hours. Because often the nurses mistakenly were concerned that a determination of “No EXPOSURE” meant that the patient would not receive necessary care, she would change such a patient’s treatment priority to “MONITOR” or “URGENT” even though the just-in-time training stressed that exiting the IGSA process

resulted in the patient being rerouted to normal hospital triage. To minimize the nurses' second guessing the algorithm, it has been revised so that every patient is triaged through all the steps and decision points to identify anyone in need of URGENT care—only then is a determination made to MONITOR or return to the hospital system to be triaged.

An $\text{SpO}_2 < 92$ percent is always considered a danger zone vital sign and it has been emphasized in the revised algorithm by placing it with the other vital signs and highlighting it with a red background. In addition, the abnormal vital signs were relabeled to reduce confusion. Another critical change was the flow of the IGSA triage algorithm which was redesigned by the research team to include process end points and recommended actions. The IGSA triage algorithm uses a three-stage triage process:

1. *Primary Triage* where all patients entering the ED are quickly assessed for any life-threatening S/Sx that requires “Immediate” intervention such as an unresponsive patient. These patients are treated immediately.
2. *Kiosk* is where all patients who are not triaged as “Immediate” are directed to enter their information into mobile devices that can be quickly deployed in the ED.
3. Patients are then directed to the *Secondary Triage* nurse who reviews the patient information and assesses the patient to make a final determination of his/her triage status. Factors considered in the triage status include:
 - a. *High-risk* patients who require “Urgent” care (ie, an SpO_2 of < 92 percent). Other abnormal vital signs identified in the algorithm are also considered as well as any other S/Sx determined by the nurse to require “Urgent” attention.
 - b. *Exposure status* to an IGSA chemical. A mobile application will be developed using Google Maps to identify geographical clusters of patients with S/ Sx of a chemical exposure and to alert the nurse if the patient's address falls within the geographical cluster area.
 - If the patient does not exhibit an IGSA syndrome and the address falls outside the exposed geographic cluster area, the patient is triaged as “Not Exposed” and directed to the usual “Hospital System” for further assessment and treatment. If the patient exhibits an IGSA syndrome or the address indicates the patient was within the exposed geographic area but the exposure is beyond the latency period, the patient is classified as “Do Not Monitor” and directed to the usual “Hospital System” for further assessment and treatment. In the revised IGSA algorithm, the latency period was changed from 6 to 8 hours, because the latency period for most IGSA chemicals is 8 hours.
 - If the patient exhibits IGSA syndrome S/Sx that began within the past 8 hours or their address was within the exposed

geographic cluster area, the patient is classified as “Monitor.” These patients will be monitored throughout the latency period for S/Sx of concern.

Figure 7 incorporates all changes into a revised IGSA triage algorithm.

Conclusions

The IGSA triage algorithm is intended to be used at the first indication that a surge of patients into their ED is related to a chemical incident. Our results revealed that the IGSA triage algorithm was more precise and accurate than the ESI algorithm and rated very favorably by the nurses who used the IGSA triage algorithm during the exercise. The research team’s next steps are to incorporate the algorithm into a prototype ED Informatics Chemical Tool (EDICT) that will provide a flexible, robust, and scalable informatics computational solution for ED response during chemical MCIs. EDICT will be designed to be downloaded onto any mobile device (ie, tablet computer, mobile phone, etc).

A spill of chemicals moving through a major city could injure or kill thousands of people. Improvements in disaster informatics related to ED triage during chemical MCIs may save thousands of lives. Therefore, the proposed solution, EDICT, is essential to manage chemical MCIs and may dramatically improve the way patients are processed in EDs to quickly identify victims of a chemical MCI and triage them efficiently and accurately using the validated IGSA triage algorithm. A computer simulation exercise proved a cost effective and efficient strategy for testing two triage algorithms and validating that the IGSA triage algorithm is more accurate and precise in managing patients’ post chemical exposure.

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Figure 1.
S/Sx associated with IGSA syndrome.

Figure 2.
IGSA triage algorithm developed based on IGSA chlorine S/Sx characterization.

Figure 3.
ESI algorithm.¹³

Patient ID	Age	Sex	Chlorine Exposure
1003-T	37	Female	No
Pulse Ox (%)	Pulse	Respirations	Pain Scale
94	104	22	0
Chief Complaint			
Pt. c/o chest tightness and wheezing this morning with nonproductive cough. Pt has run out of her medications for her asthma. SOB.			

Figure 4.
Patient card sample for the computer simulation.

ESI Questions

Record ID	7
Nurse ID <small>* must provide value</small>	17
Start time <small>* must provide value</small>	2016-04-23 09:25:11 <small>Press "Now" to the right of the box</small>
Patient ID <small>* must provide value</small>	1013-T <small>Example: 1003F, 2045T, 3145W</small>
Select age category <small>* must provide value</small>	☐ Age less than 3 months ☐ Age between 3 months and less than 3 years ☐ Age between 3 and 8 years ☒ Age over 8 years
What problem brought you to the hospital today? <small>* must provide value</small>	Irritated throat <small>Expand</small>
LEVEL 1 ASSESSMENT	
Does the Patient Require Immediate Life-Saving Intervention?	☒ Yes ☐ No
If Yes, which of the follow criteria apply? (Check all that apply)	☐ Intubated by EMS ☐ Apneic ☐ Pulseless ☐ Severe respiratory distress ☐ SpO2 < 90% ☐ Unresponsive ☐ Pulse rate, rhythm, and quality is life threatening?
Patient meets criteria for LEVEL 1 <small>* must provide value</small>	☒ Yes ☐ No
LEVEL 2 ASSESSMENT	
Is this a patient who shouldn't wait? Consider: Would I give my last open bed to this patient?	☒ Yes ☐ No
If Yes, which of the following criteria apply ? (Check all that apply)	☐ Is this a high-risk situation? ☐ New onset of confusion, lethargy or disorientation? ☐ Severe pain or distress in light of clinical situation?
Patient meets criteria for LEVEL 2	☒ Yes ☐ No
VITAL SIGNS ASSESSMENT	
Are there Danger Zone Vital Signs?	☒ Yes ☐ No
If Yes, which of the following criteria apply? (Check all that apply)	☐ SpO2 < 92 % ☐ Respirations: age > 8 years, > 20 ☐ Heart Rate: age > 8 years, > 100
Patient meets criteria for LEVEL 2	☒ Yes ☐ No

RESOURCE ASSESSMENT	
How many different resources are needed?	☐ None ☒ One ☐ Two or more
Resources (Check all that apply)	☒ Labs (blood, urine) ☐ ECG ☐ X-rays ☐ CT-MRI-ultrasound ☐ Angiography ☐ IV fluids ☐ IV medicines ☐ IM medicines ☐ Nebulized medications ☐ Specialty consultation ☐ Simple procedure =1 (laceration repair, foley cath, eye irrigation) ☐ Complex procedure =2 (conscious sedation)
Patient meets criteria of two or more resources for LEVEL 3	☐ Yes ☒ No
Patient meets criteria of one resource for LEVEL 4	☒ Yes ☐ No
Patient meets criteria of no resources for LEVEL 5	☐ Yes ☒ No
FINAL DECISION	
Calculated Level	<input type="text" value="4"/> View equation
Do you agree with LEVEL shown?	☒ Yes ☐ No
* must provide value	

Figure 5.
Sample REDCap form for the ESI algorithm survey.

Igsa Questions

Record ID	17
Nurse ID <small>* must provide value</small>	<input type="text" value="11"/>
Start time <small>* must provide value</small>	<input type="text" value="2016-04-23 09:30:31"/> <small>Press "Now" to the right of the box</small>
Patient ID <small>* must provide value</small>	<input type="text" value="4014W"/> <small>Example: 1003F, 2045T, 3145W</small>
Select age category <small>* must provide value</small>	☐ Age less than 3 months ☐ Age between 3 months and less than 3 years ☐ Age between 3 and 8 years ☒ Age over 8 years
What problem brought you to the hospital today? <small>* must provide value</small>	<input type="text" value="swollen tonsils sore throat"/> Expand

LEVEL 1 ASSESSMENT

Does the Patient Require Immediate Life-Saving Intervention? <small>* must provide value</small>	☐ Yes ☒ No ☐ Intubated by EMS ☐ Apneic ☐ Pulseless ☐ Severe respiratory distress ☐ Unresponsive
If Yes, which of the follow apply? (Check all that apply)	
Patient meets criteria for LEVEL 1 <small>* must provide value</small>	☐ Yes ☒ No

SYNDROME ASSESSMENT

Is patient experiencing a respiratory problem?	☐ Yes ☒ No ☐ Shortness of breath ☐ Wheezing ☐ Coughing ☐ Choking
If Yes, which of the following apply ? (Check all that apply)	
Is patient experiencing chest discomfort such as tightness, pain or burning?	☐ Yes ☒ No
Is patient experiencing pain, irritation or burning of the eyes, nose or throat?	☒ Yes ☐ No
If Yes, which of the following apply ? (Check all that apply)	☐ Eyes ☐ Nose ☒ Throat
Are two or more of the items above checked? Items: Shortness of breath, Wheezing, Coughing, Choking, Chest discomfort, Eyes Nose, Throat	☐ Yes ☒ No

Patient does not meet criteria of IGSA Syndrome since two or more are not checked.

GEOGRAPHICAL AREA ASSESSMENT

Is there a known Irritant Gas Incident in the local area? ☐ Yes ☒ No

EXPOSURE ASSESSMENT

When NO to IGSA Syndrome and NO to known Irritant Gas then **NOT EXPOSED** View equation
Ignore number in this box.

STOP IGSA assessment process.
(Skip to the **FINAL TRIAGE ASSESSMENT** section at bottom of form)

VITAL SIGNS ASSESSMENT

SpO2 ☐ < 92% ☒ ≥ 92%

Check for abnormal Respirations and Heart Rate ☐ Respirations: > 20
☐ Heart Rate: > 100

Does the combined assessment of SpO2, Respirations, and Heart Rate warrant **urgent** attention?
NOTE: SpO2 < 92% is always categorized as **urgent**. ☐ Yes ☐ No

FINAL TRIAGE ASSESSMENT

Exposure status: **NO EXPOSURE**

Do you agree with the exposure status? ☒ Yes
☐ No
* must provide value

Figure 6.
Sample REDCap form for the IGSA triage algorithm survey.

Figure 7.
 Validated version IGSA triage algorithm.

Table 1.

Triage exercise survey questions and measures

Questions	Measure
1. How would you rate the quality of this triage tool?	Likert scale: 1 = Low quality, 2 = Neither high nor low quality, 3 = High quality, 4 = Very high quality
2. How easy is it to understand the information on this triage tool survey?	Likert scale: 1 = Not so easy, 2 = Somewhat easy, 3 = Very easy, 4 = Extremely easy
3. How likely would you be to use this triage tool?	Likert scale: 1 = Not at all likely, 2 = Slightly likely, 3 = Moderately likely; 4 = Very likely, 5 = Extremely likely
4. What does this triage tool do really well?	Free text comments
5. How can we improve this triage tool?	Free text comments

Table 2.

Kappa agreement and 95% CI*

Nurse Pair IDs	ESI triage algorithm			IGSA triage algorithm		
	Simple κ	95% CI	Weighted κ	95% CI	Simple κ	95% CI
1 and 9	0.03	0.01-0.13	0.12	0.01-0.23		
5 and 12	0.08	0.03-0.19	0.18	0.08-0.28		
8 and 14	0.31	0.18-0.45	0.51	0.39-0.62		
10 and 22	0.23	0.10-0.37	0.41	0.27-0.54		
16 and 24	0.18	0.03-0.32	0.32	0.18-0.46		
17 and 21	0.40	0.27-0.52	0.49	0.36-0.62		
2 and 15					0.71	0.59-0.84
3 and 19					0.54	0.43-0.66
4 and 11					0.68	0.56-0.80
7 and 18					0.65	0.53-0.76
13 and 25					0.83	0.73-0.93
20 and 23					0.80	0.70-0.91
9 and 26					0.83	0.73-0.93

* κ : 0.0-0.2 = Poor; 0.21-0.4 = Fair; 0.41-0.6 = Moderate; 0.61-0.8 = Good; 0.81-1.0 = Very Good.

Kappa agreement and 95% CI with Gold Standard*

Sample groups	ESI triage algorithm				IGSA triage algorithm			
	Simple κ	95% CI	Weighted κ	95% CI	Simple κ	95% CI	Weighted κ	95% CI
2005	0.23	0.19-0.27	0.36	0.32-0.39	0.77	0.73-0.81	0.85	0.82-0.88
2015	0.18	0.12-0.24	0.32	0.26-0.37	0.72	0.67-0.77	0.81	0.77-0.85

* α : 0.0-0.2 = Poor; 0.21-0.4 = Fair; 0.41-0.6 = Moderate; 0.61-0.8 = Good; 0.81-1.0 = Very Good.

Table 4.Precision and 95% CI^{*}

ESI triage algorithm		IGSA triage algorithm	
Precision percent	95% CI	Precision percent	95% CI
0.73	0.69-0.77	0.82	0.78-0.85

^{*} Precision: 0.0-0.2 = Poor; 0.21-0.4 = Fair; 0.41-0.6 = Moderate; 0.61-0.8 = Good; 0.81-1.0 = Very Good.

Table 5.

Mean triage duration with standard deviation

ESI triage algorithm		IGSA triage algorithm	
Mean triage duration	SD	Mean triage duration	SD
100.70 s	62.87	104.49	54.41

Table 6.

Means and standard deviation of computer simulation survey by triage algorithm

Variables *	ESI triage algorithm (n = 13)		IGSA triage algorithm (n = 12)	
	Mean	SD	Mean	SD
Q1 Tool quality	3.46	0.88	4.42	0.51
Q2 Understanding	3.85	0.80	4.33	0.65
Q3 Use	3.00	1.35	3.92	1.08

* *t* test p value = 0.0033 and Wilcoxon two-sample test p value = 0.0053.